The Ultimate Caliber:

Myth or Reality?

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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Famous Caliber Studies of Years Past

1. *Thompson-LaGarde Pistol Caliber Study*
2. *John Douglas Pedersen's 1924 Caliber Study*
3. *SAW 1972-1974 Caliber Study*
4. *NATO Point Defense Weapon Caliber Study*

Politics Counts

5.56mm? 6.5mm? 6.8mm? 7mm? 7.62mm? 8mm?

What's Most Important?
Depends on who you ask…

- Barrier Penetration Potential
- Consistency / Shelf Life
- Cost
- Manufacturability
- Minute of Angle
- Muzzle Flash / Weapon Signature
- Muzzle Velocity
- Recoil
- Safety
- “Stopping Power”
- Versatility
- Weight

What's best? It all depends…

1. Is your target frequently protected or behind barriers? What type? How often?
2. Do you have legal restrictions which prohibit certain designs?
3. What is the range of interest? Are these ranges all equally important?
4. How many missions and weapons is that ammunition expected to service?
5. Are there any cost or manufacturing or environmental constraints?
6. What can't you live without and what do you absolutely have to have?

Jack of all trades… Master of none…

Can’t optimize against everything, and for everyone…

1. *One factor may affect many others.*

2. *The influence of each factor on another is not constant.*

3. *What performance sacrifices are you willing to make on the high end to bring up performance on the low end?*

Test Limitations & Results

1. How do you test each factor?
    - Statistical Nature of Ballistics (Performance Bands)
    - The indirectness of tests
    - The complexity of tests

2. How do you convey test results to your customer?
    - The simplicity problem
    - The time problem
    - The preconceived notion problem
    - The “not invented here” problem

“The problem with small arms isn’t that there aren’t experts. The problem is that everyone is an expert.”

More Food for thought…

- From historical observations, most encounters happen at 100m or less. The ammunition expenditure per casualty ratio for these conflicts is usually hundreds or thousands to one.

- The average engagement range of an encounter is highly dependent upon the weather, terrain, and light conditions of that setting.

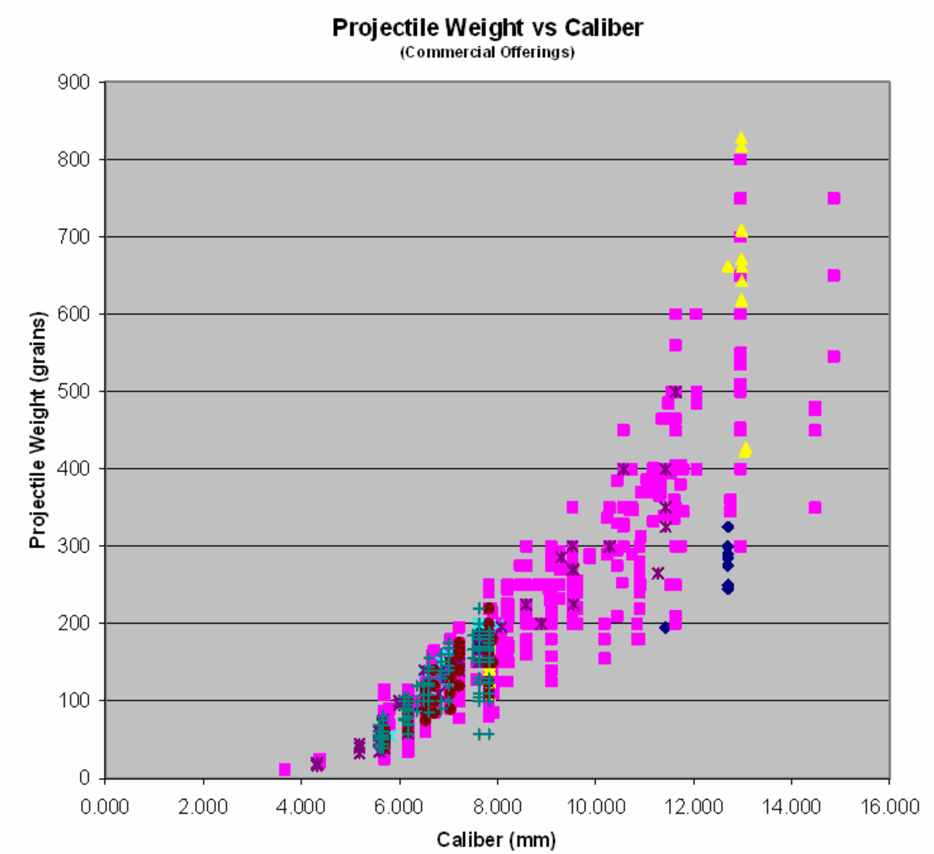
- Target exposure time is usually mere seconds. In many instances, they are going to ground by the time they are observed. They may be protected by high, low, or no tech.

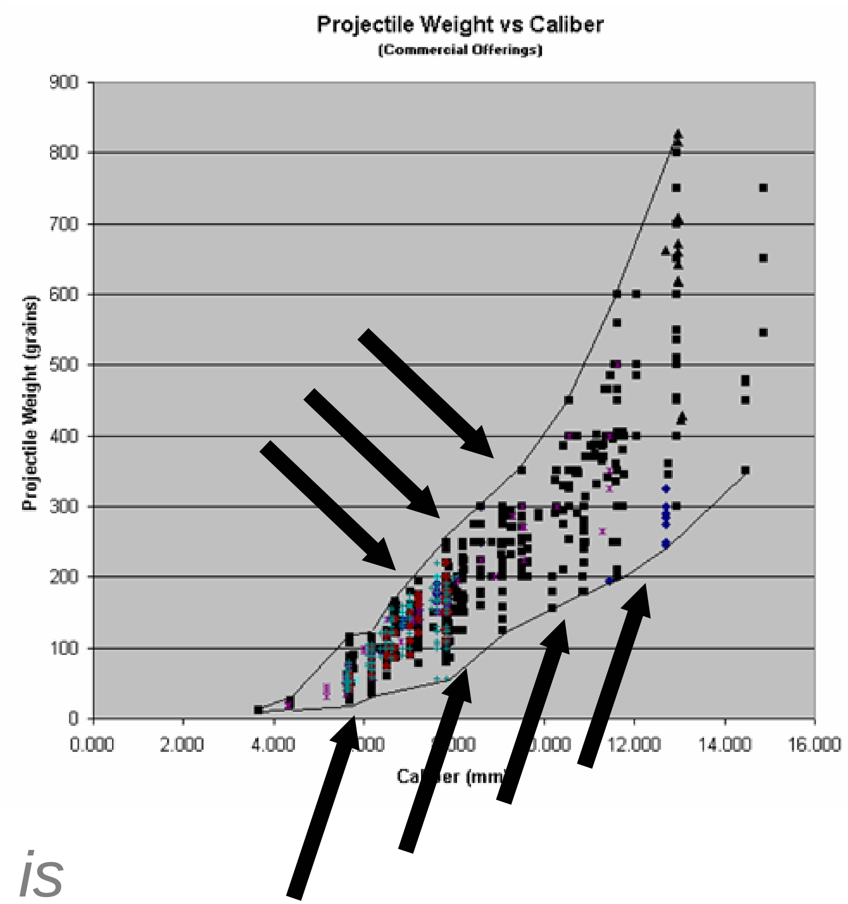
- We don't know where the next war will be fought, and we must be prepared to fight in multiple settings at the same time.

- Soldiers must be comfortable, proficient, and confident with their weapons. Multiple weapons for individual settings is not considered optimal. However, specific weapons are not expected to be employed at every operational range.

"Fight as you train. Train as you fight."

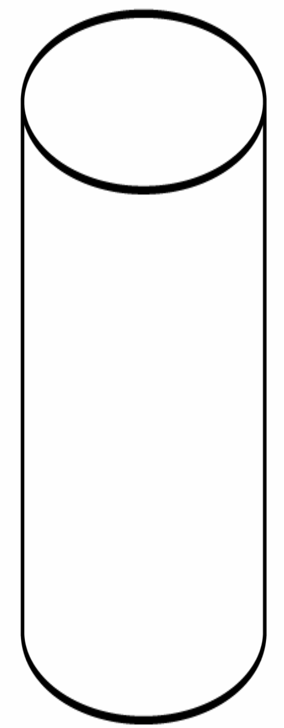
What's Out there?
The Commercial Projectile Weight Envelope





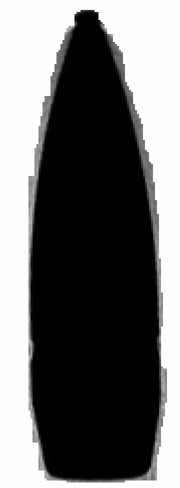
Anything in between the arrows is probable.

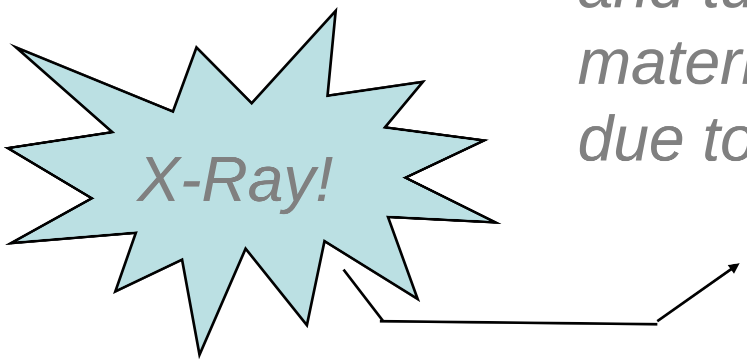
Why the range?



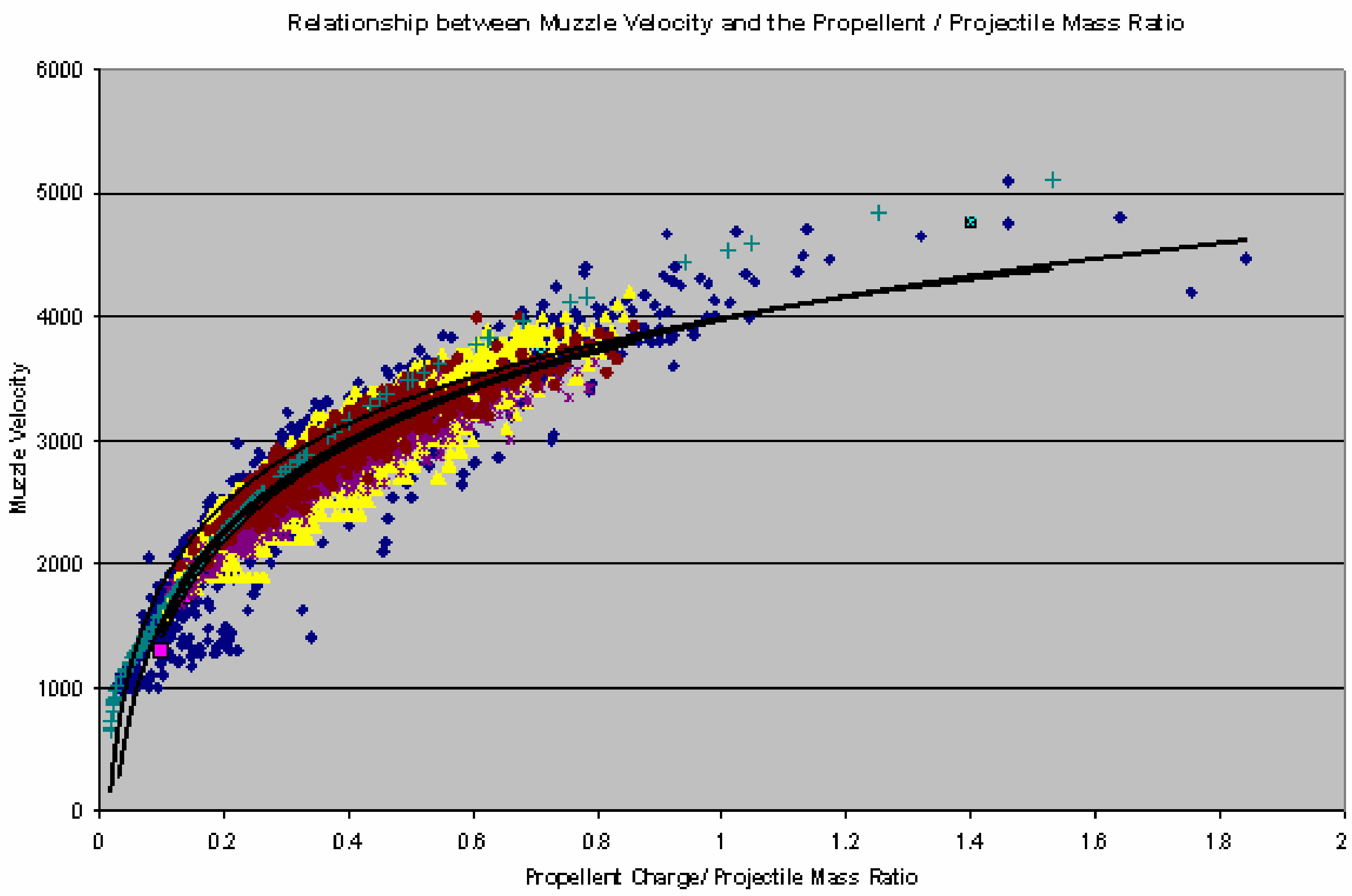
1. Projectiles have a relatively small range of length to diameter ratios that have desirable flight characteristics.

2. The bulk of projectiles are usually composed of materials with a density between steel and tungsten. Lower density materials are used sparingly due to various constraints





Relationship between Propellant Wt, Projectile Wt, and Muzzle Velocity



Why this Range?

1. Shooters can only adjust for a certain level of launch recoil. (accuracy)

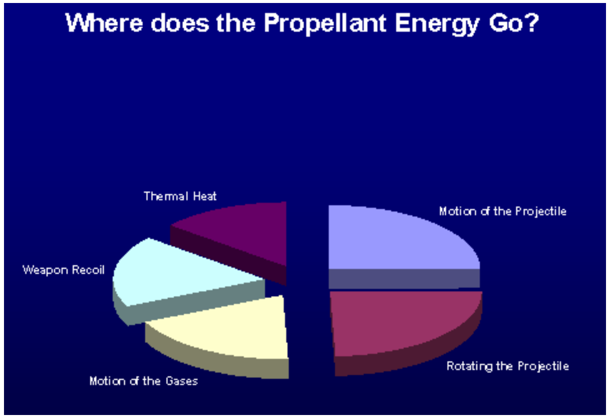
2. Shooters don't want long barrels, but long barrels are required to obtain the upper range of muzzle velocity.

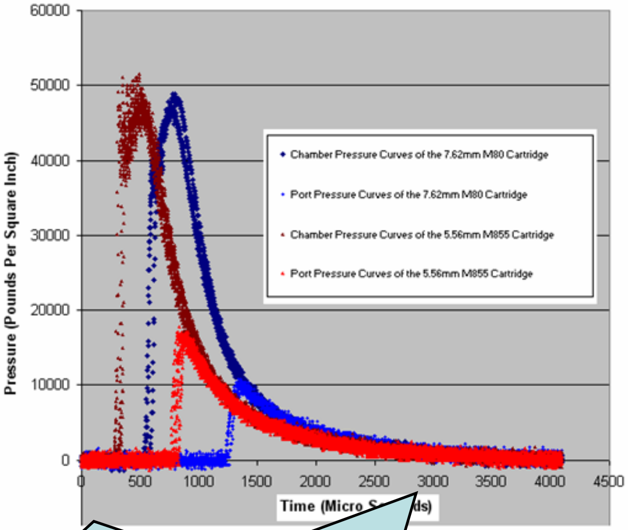
3. Pressure constraints limit overall chamber pressures and projectile velocities

4. Propellant gas physics puts an upper constraint on projectile velocities.

5. Cartridges are used in multiple weapons with different constraints (e.g. M4-10 inch barrel and SAW)

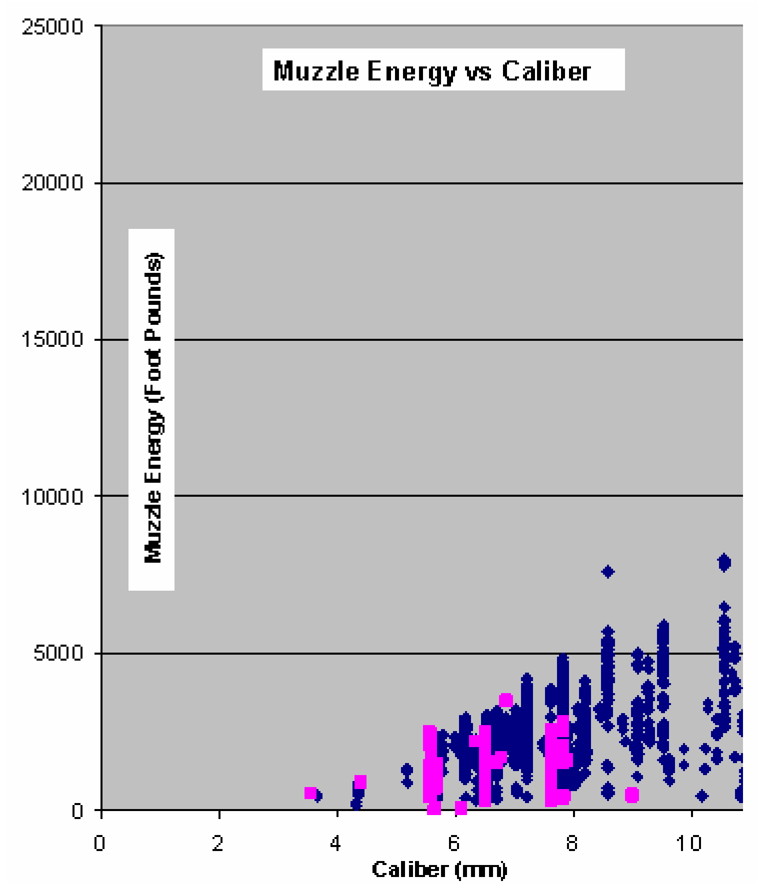
6. Cartridge Volumes





High pressures at muzzle exit result in muzzle flash!

Muzzle Energy vs. Caliber

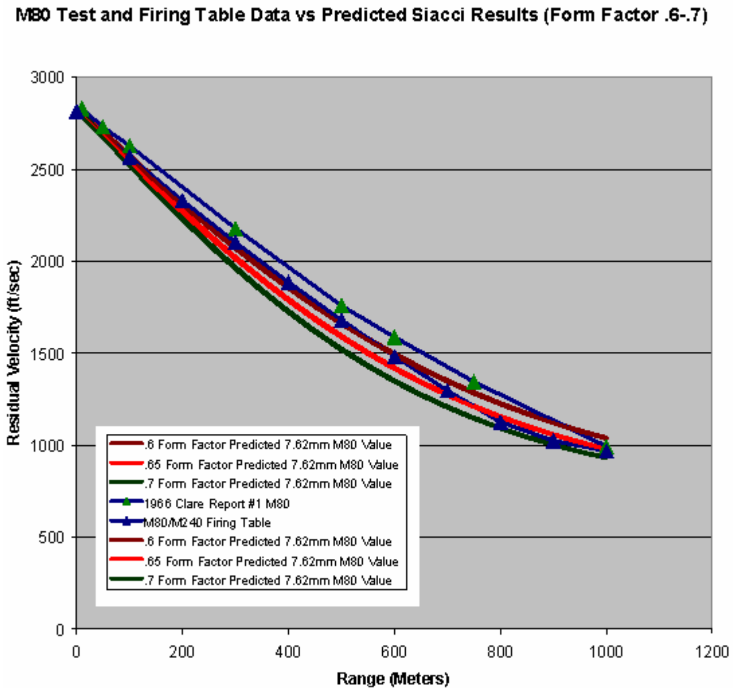


1. Again wide range of values.
2. Depends upon the constraints of the system in question
3. No one answer per caliber.

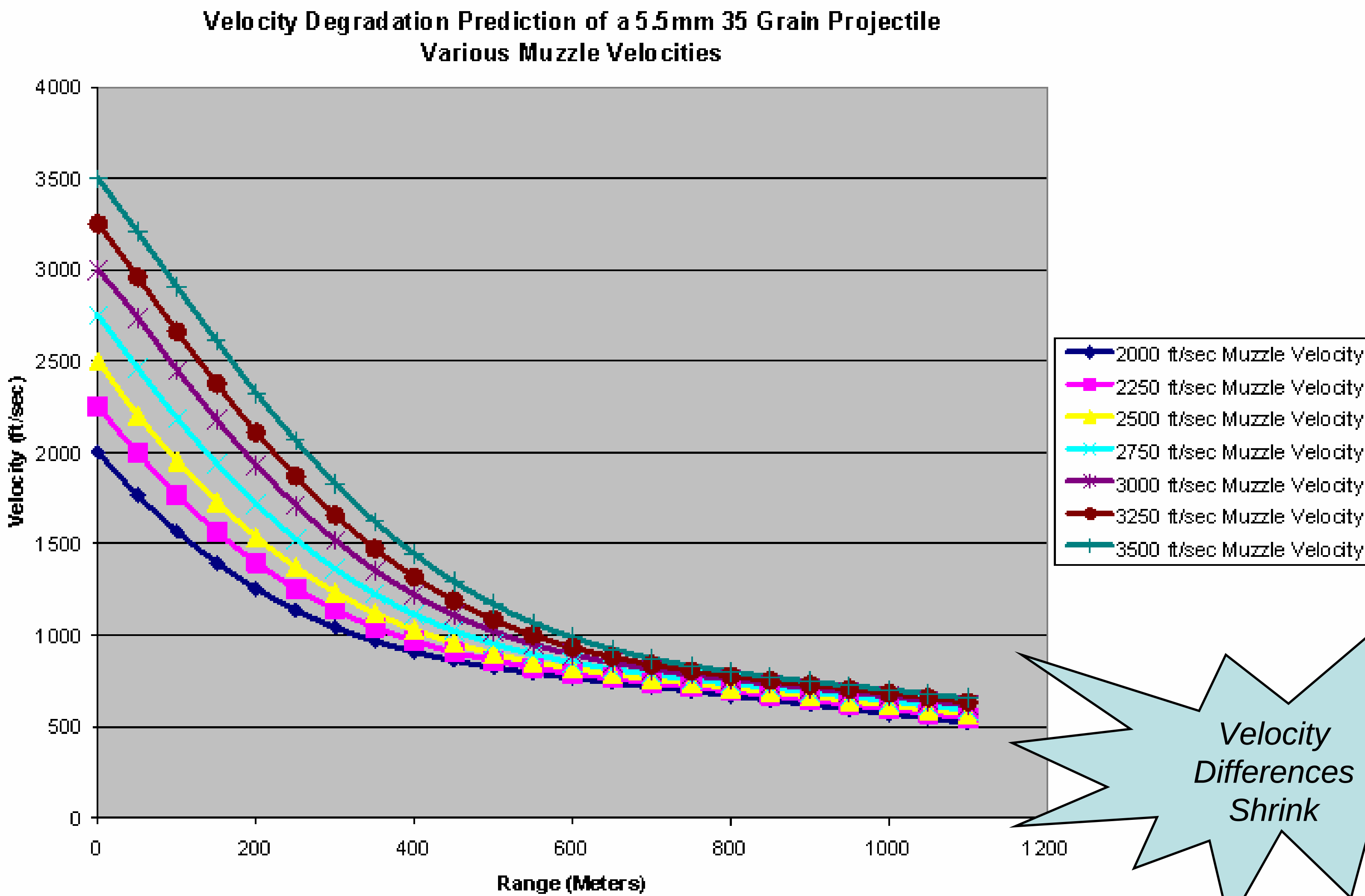
Shape does matter.

- In the next few slides you will see some residual velocity curves that were generated using the Siacci method. This is a theoretical approximation for example purposes.

- The curves reflect shapes that are not atypical of military projectiles. However, drag is a complicated area, and specifics will vary.

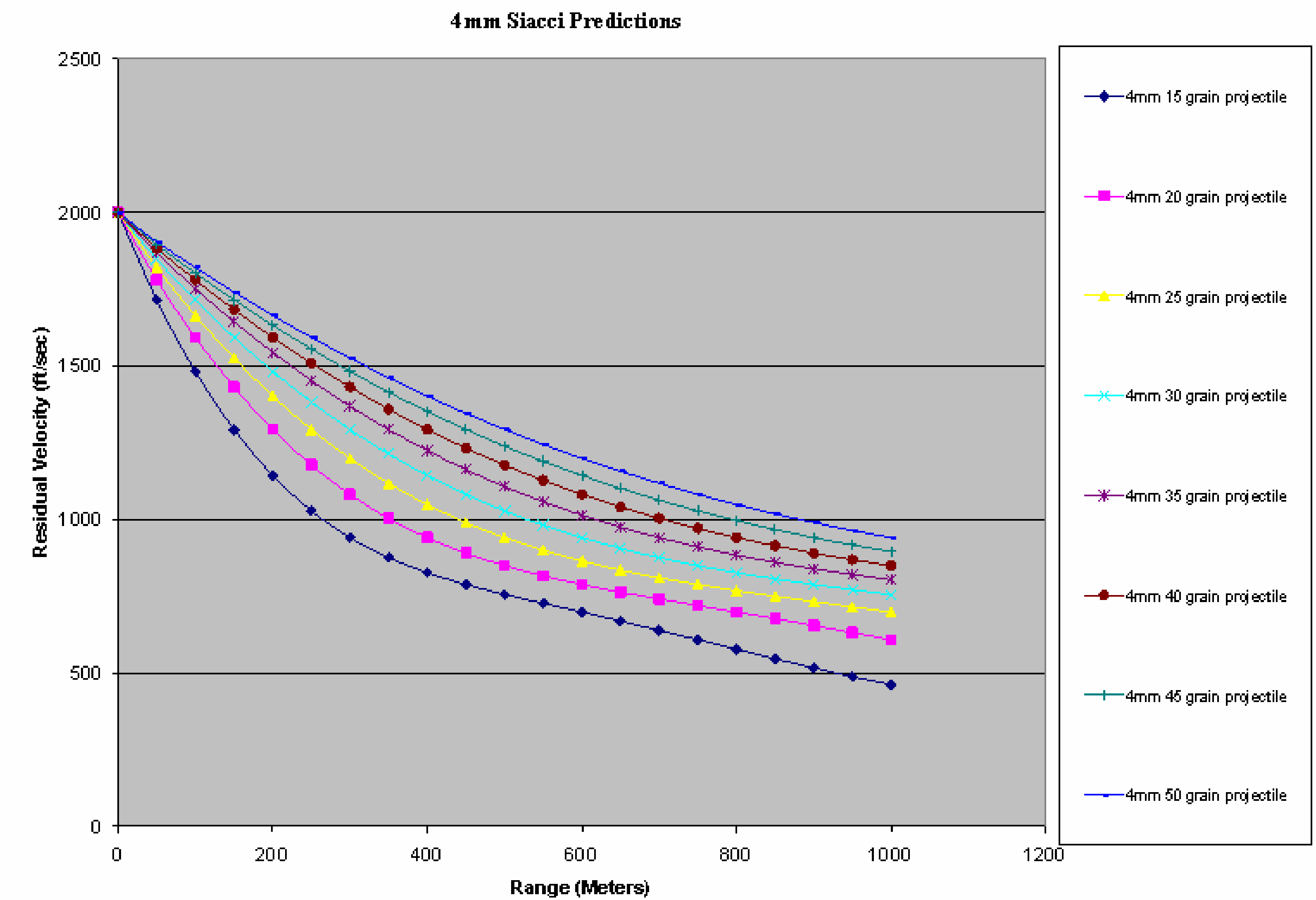


Residual Velocity at Range & Muzzle Velocity

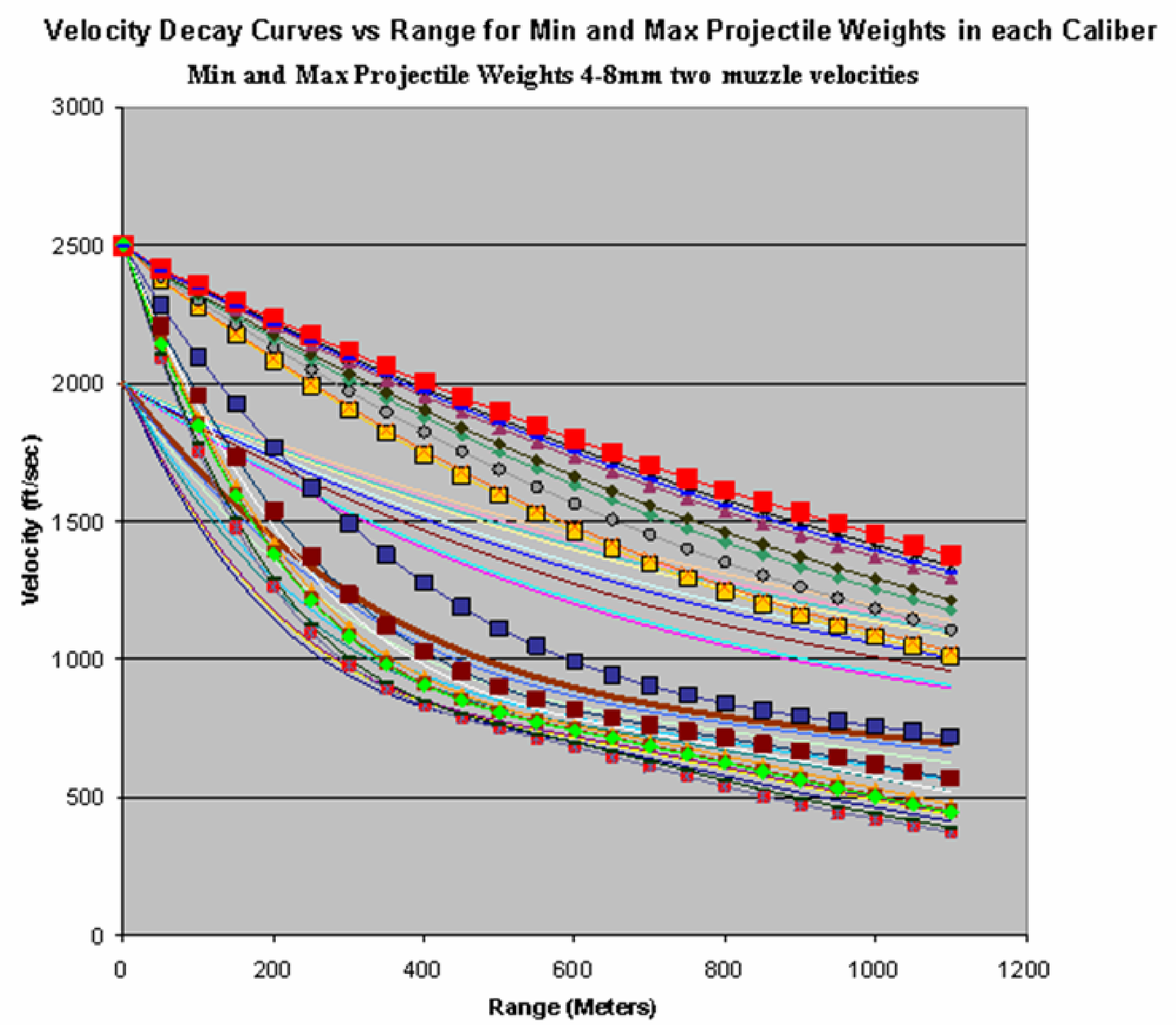


Velocity Differences Shrink

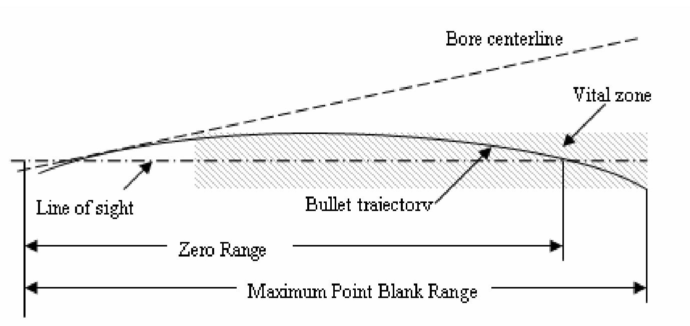
Residual Velocity at Range and Projectile Mass



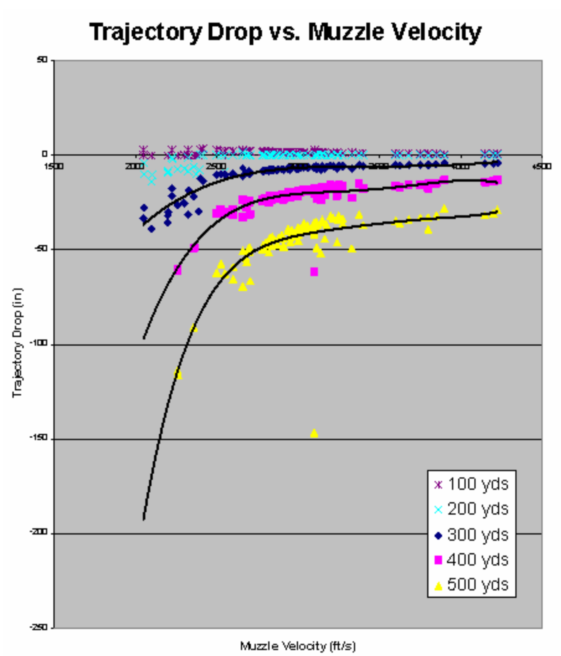
Two sets of curves…

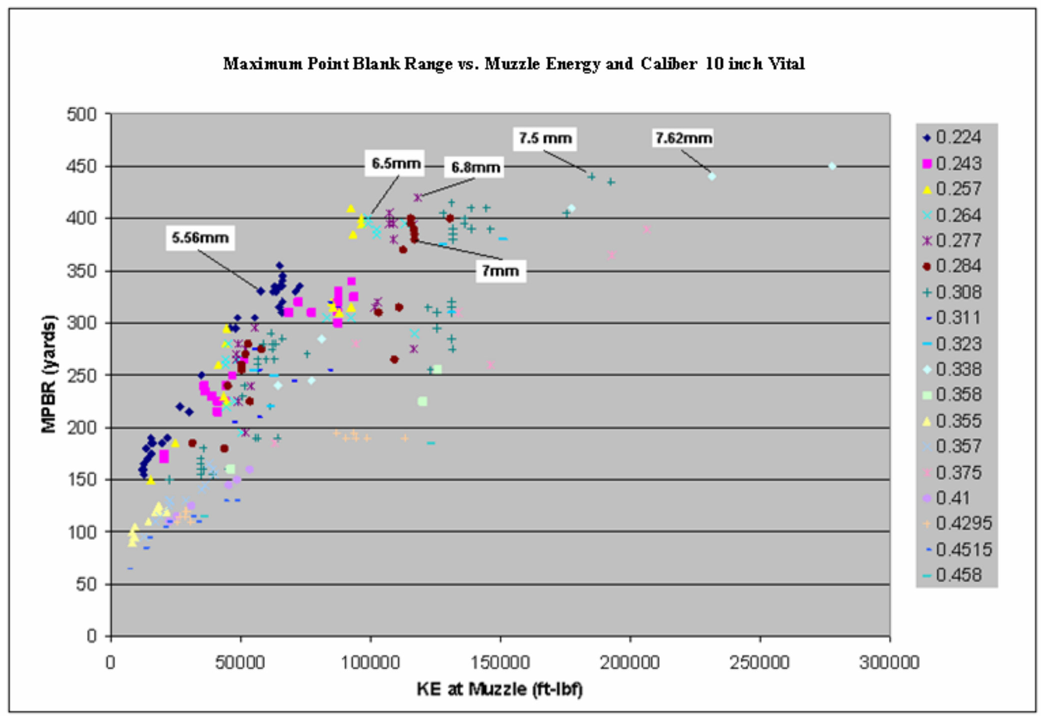


Max Point Blank Range, Precision & Caliber

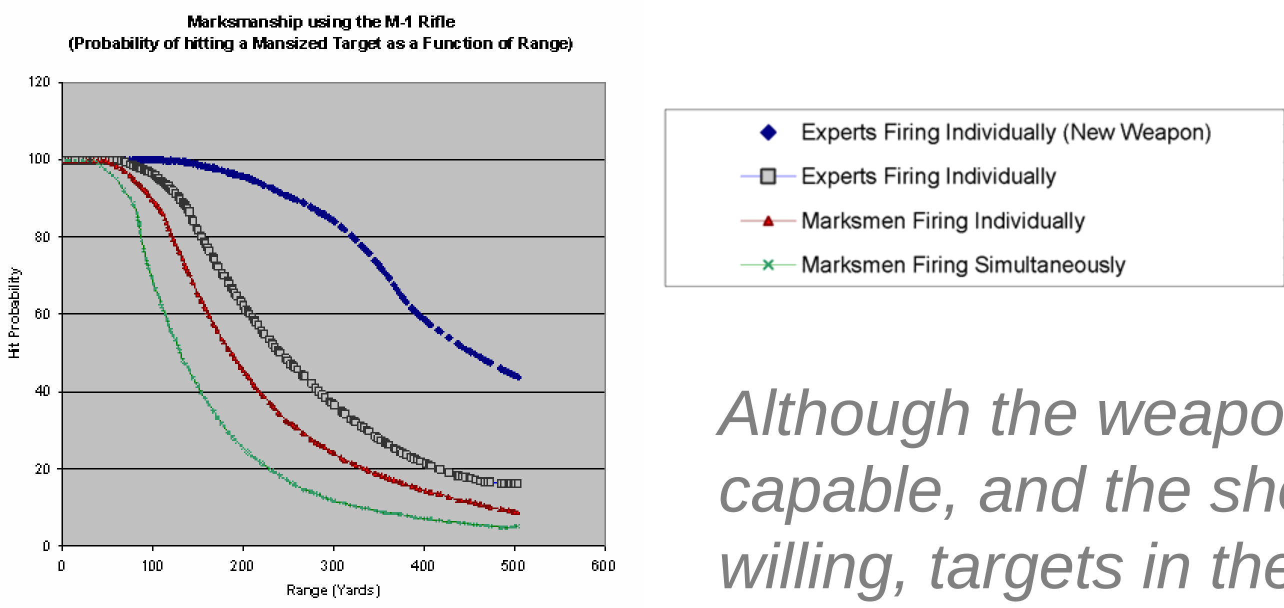


Projectiles should be "zeroed" for as great a span of ranges as possible without readjustment of the sights.

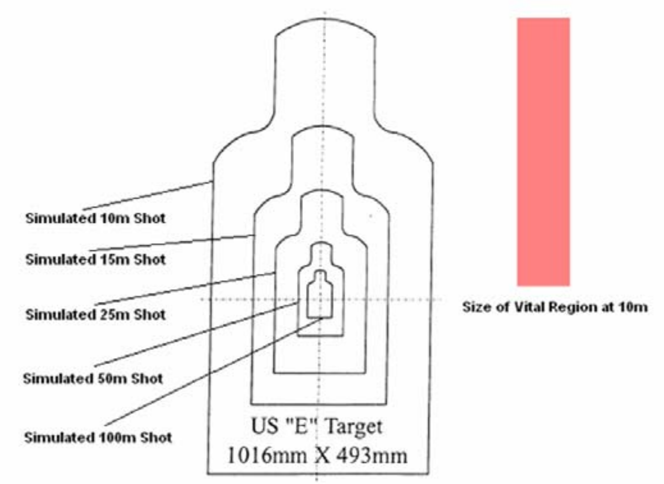




The Rest of the Story…
Precision vs. Accuracy



Although the weapons may be capable, and the shooters may be willing, targets in theatre are not hit as often as one would like.



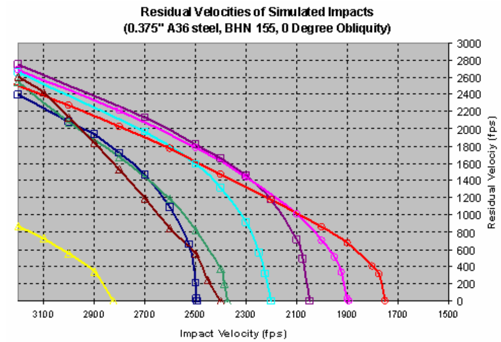
Recoil, Time to Acquire, Stress, and Target exposure time all play a part in limiting the accuracy of the weapon in field scenarios

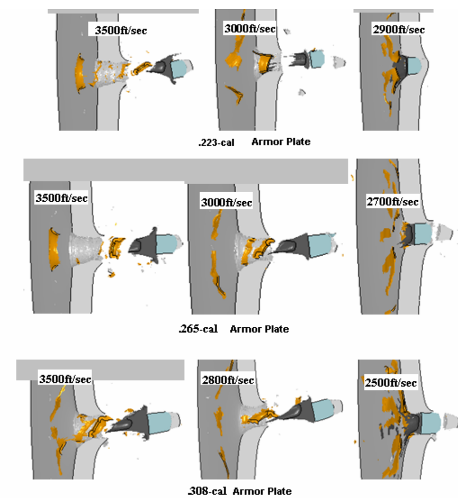
Getting to the Target…

- Many intermediate barriers on the typical battlefield.

- The -- after barrier effectiveness -- of many projectiles is often of prime importance.

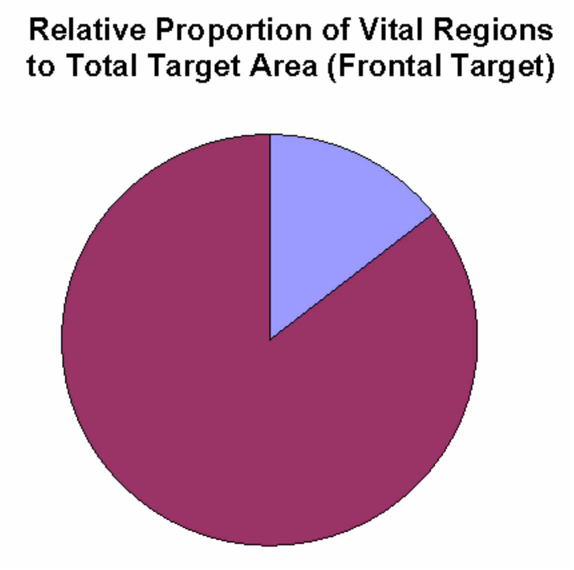
- Projectile penetration effectiveness is tied to the physical characteristics of the projectile, the target, and the impact particulars.

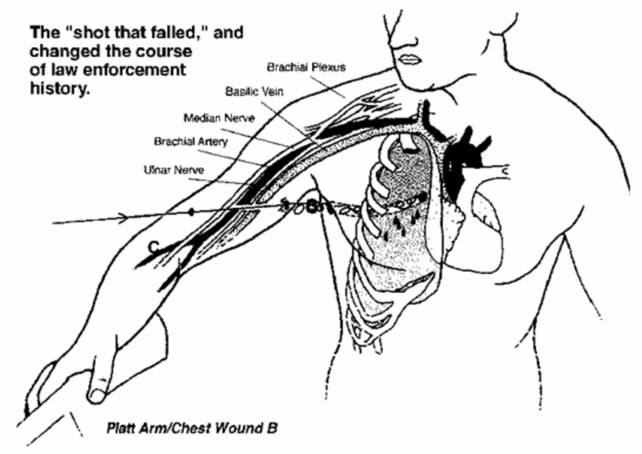




Barrier penetration in many instances is tied to caliber, impact velocity, hardness, density, mass, thickness, angle of attack, obliquity and overall geometry

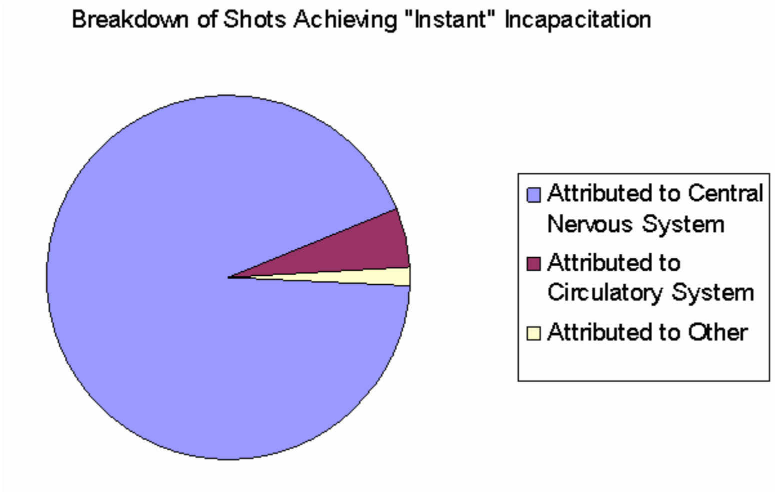
A look at Incapacitation



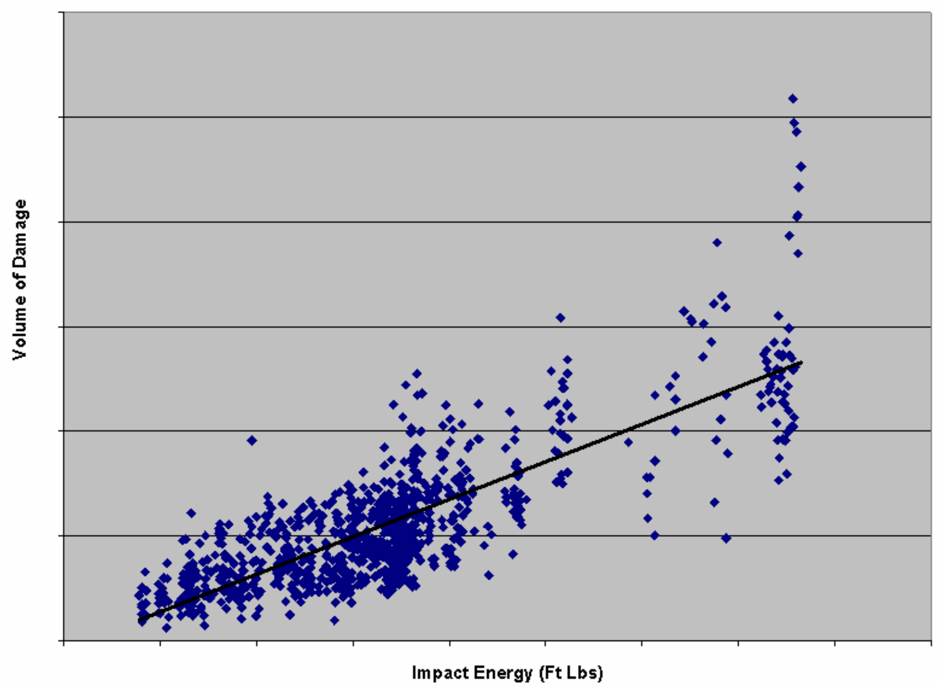


"Not all impacts are equal."

Psychology plays a role in many instances of "instant incapacitation".



Effectiveness varies considerably (even within a caliber)

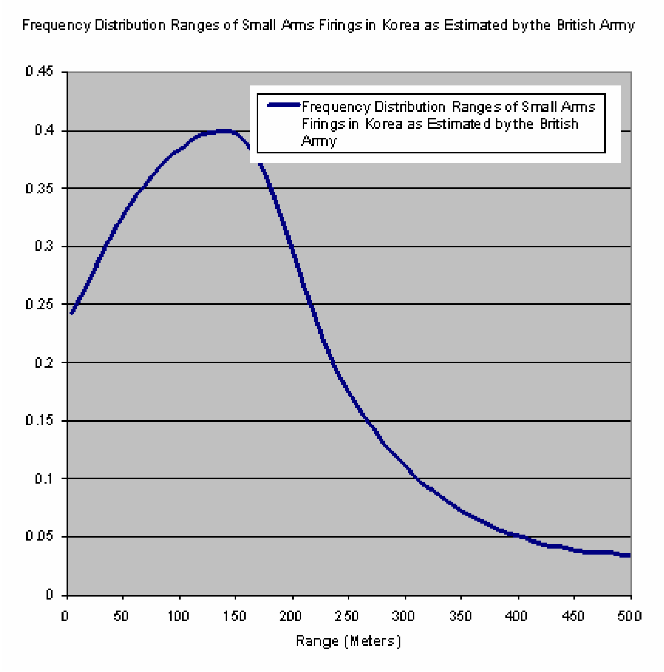


Author	Metric of Performance	Year
Benton[99]	Full penetration of sheets of fir wood	1867
Rhone	Impact KE: 58 Foot-Pound Rule	1896
Zuckerman[100]	$(mass^{.04})*(velocity)$	1942
Callendar	$(mass)*(velocity)^3$	1942
Gurney	$(mass)*(velocity)^3$	1944
McMillan & Gregg	250 ft/sec Impact Velocity in Vulnerable area	1945
Allen & Sperrazza	function of $(mass)*(velocity^{3/2})$	1956
Dziemian	Energy Deposited in 15 cm	1960
Sturdivan	Energy Deposit adjusted by Depth	1975
Bruchey	Semi-Empirical Virtual Assessment	1979

- *Impact energy is like a budget. If your budget is large, there is a lot that you can, but not necessarily will, do. If it is small your choices are limited.*

Yaw at impact, projectile shape, and projectile ruggedness all contribute to how effective a particular projectile/fragment spends its budget after impact. Very difficult to gauge and very controversial

Putting it all together….



Beyond basic performance analysis lies the difficult task of putting it all together.

The expected frequency and importance of different events will largely guide the analyst towards his final answer.

Mathematical weighting plays a significant and controversial role here.

The Reality

- Best caliber evaluations are closely tied to the requirements.
- Several configurations will generally be capable of meeting generalized performance criteria.
- Larger calibers typically:
  - Weigh more
  - Bring more energy to distant targets
  - are more effective against barriers.
  - are less accurate.
- Smaller calibers typically:
  - weigh less
  - bring very high energies to targets at short ranges
  - are effective against many intermediate barriers
  - are more accurate

Most historical rifle caliber studies have yielded an optimal value between 6.5mm and 7mm